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Cortical Arousal Strategies in Left-Handers during the Aural Perception and Manual Playback of Mono- and Polyphonic Rhythmical Patterns

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Abstract: The actual purpose of this study is to establish the cortical arousal strategies (according to the power of the EEG (electroencephalogram) α-oscillations) during the aural perception as well as manual playback of mono- and polyphonic rhythmical patterns in men with left profile. The study involved 35 men from 19 to 21 years old with the left profile of the manual and aural asymmetries. EEG was recorded in the functional status of rest: during the aural perception and playback of mono- and polyphonic rhythmical patterns with the left and right hand fingers. The monophony in the rhythmical pattern sounding relative to monophonic patterns is followed by more expressed and widespread cortical processes of the EEG α-oscillation depression. Given patterns indicate a greater intensity of ascending nonspecific arousal strategies of data processing by men on conditions of the sound and harmonious complications of the pattern structure. The aural perception and playback of rhythmical patterns with both hands were accompanied by the increased significance of arousal processes in the right hemisphere. This may be due to the dominant role of the hemisphere during the formation of the innervation impacts on the left-hander's neuro-motor apparatus. More differentiated changes in the cerebral cortex were installed during the left hand activation.

Key words: Left-handers, mono- and polyphonic sounding, alpha rhythm, rhythmic sense.

1. Introduction

The sense of a rhythm as a natural human feeling and one of the most complicated cognitive processes carried out by human mind is demonstrated in various forms of people's activities. A rhythmic sense requires a precision synchronization of several hierarchically organized movements and a careful control of temporal parameters of the stimulation [1-9]. Experimental findings [1, 3, 5, 6, 9, 10] indicate inextricable connection between auditory and motor systems in the process of the perception and reproduction of rhythmic structures. The auditory perception reflects the temporal characteristics of the current stimulus: a duration, rhythmic character, etc. The sense of movement assures the accurate presentation of the reality, speed and sequence of events [1, 3, 5, 7]. Recent electroencephalographic studies are important in revealing the central mechanisms of the sense of "rhythm". Luriia [5], Morenko, Pavlovuch [6], Boldyrieva, Gavoronkova [10] highlight specific cortical processes during the performance of the sensor-motor rhythmic tasks such as activation changes in the projection and associated areas according to the modality of sensory stimuli as well as the enhance of the synchronization between sensory and motor areas. A significant interaction between the frontoparietal areas as a criterion of the establishment of the intercentral functional relation in conditions of complications and the increased

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selective attention to it shown by Blum, Lutz and Jäncke [2], Morenko, Pavlovych [6, 11] and others. Palva [9] states that the stage of the processing sensory stimulus is accompanied by synchronized oscillations of the electrical activity of the cerebral cortex while motor responses to sensory stimuli are accompanied by processes of the arousal reaction. Methods of the positron emission tomography (PET) are used to visualize and specify a certain part of brain structures including motor and association cortex, basal ganglia and cerebellum in ensuring the synchronization of motor centers of the tempo-rhythmic auditory stimulation parameters [1, 3, 7]. Some researchers [5, 8] prove that human brain differently processes melodies and rhythms "in its pure form". According to Lotze et al. [5], Bengtsson, Ullena [1], the processing of melodies increasingly activates the right hemisphere cortex and the cerebellum otherwise the left posterior temporal cortex, ventral frontal gyri, the caudate nucleus and the cerebellum are activated by the rhythm.

The sense of rhythm as sensorimotor process is largely determined by the "personal factor", i.e., individual characteristics of sensory, motor areas and their physiological provision [1]. In this context it is interesting to investigate the specific activation processes in the cortex of individuals with different profile of sensory and motor asymmetry. The research results show that in interhemispheric provision of mental functions, there is a distinct type of asymmetric cerebral response in right-handers and, in left-handers, brain organization acquires ambilateral, diffuse, and at the same time less ordered character. The authors carried out a study of cortical arousal processes in men with a right profile [11]. According to the obtained results, their sense of rhythms is accompanied by local and differentiated arousal changes in the cerebral cortex. The higher prevalence of processes of the EEG α-rhythm depression was ascertained in the left hemisphere in case of the task performance with a right hand while with the left hand—in the right hemisphere. The increasing complexity of pitch and harmony of rhythmic patterns (polyphonic sounding) is accompanied by the growing role of non-specific information processing strategies during the manual playback.

Despite the progress in this problem investigation, the elucidation of the features of integrated upstream and downstream information processes, correlation of local and generalized activation of men with different profile of functional asymmetry still remain relevant. The investigation of how the pitch and harmonic complexity of the structure of sensory stimuli impacts on the nature of the cortex electrogenesis is of particular interest. The context of this issue determined the purpose and objectives of this study: establishing cortical arousal strategies (according to the power of the EEG α-oscillations) during the aural perception as well as manual playback of mono- and polyphonic rhythmical patterns in men with left profile.

2. Methods

Thirty-five 19-21 years old men with a sinistral profile of the auditory and manual asymmetries participated in a study with the observance of biomedical ethics [2]. Testees had no music education or systematic practice of making music.

The electrical activities of the cerebral cortex recorded by means of the hardware and software complex "NeuroCom" ("KHAI-Medica", state registration certificate No. 6038/2007 from Jan. 26, 2007) was considered as the indicator of data processes. Active electrodes were placed in nineteen points on the scalp under the international system of 10/20 while writing the EEG. 40 second intervals of EEG were registered. The spectrum of power fluctuations (μV^2) in the α-range (8-13 Hz) was calculated by means of the Fourier's fast transformation for the EEG non-artifact periods. Results within a group of men were averaged both for each lead and test. During the test, the testees were in a room isolated from light and sound, had their eyes

closed and were in a stepped-lying position in a chair with a headrest. EEG was recorded in the functional status of rest (background) during the acoustic sensation and manual playback of sound stimuli (by tapping with the fingers of the left and right hands organized in rhythmical patterns). Stimuli (Finale-2006) were sent by means of four binaural acoustic systems placed in different corners of the room at the distance of 1.2 m from both of the testee's ears. The stimulus duration was 140 ms; the output volume from acoustic systems did not exceed 55-60 dB (regulated by DE-3301 sound level meter No. 0507011882, state registration certificate No. 025-2009, valid until December 21, 2014).

All patterns include single and twin stimuli and reproduced by tests such as to this rhythmic picture—"/ // // /". Drumbeat sounds of the identical height were used as stimuli in the monophonic patterns. The polyphony in the pattern sounding was achieved by the complexity of their pitch levels and harmonic structures. Piano melody sounds with different pitch levels were superimposed onto the sounds of the drumbeat. Both sounds of drumming and playing the piano were delivered by the homophone rhythmic picture and created a harmonious sound effect of instruments. Testees received patterns of just one type from the refrain and performed tasks with only one hand.

Analyzing the results, the authors evaluated the qualitative changes of dynamic processes occurring in the cerebral cortex.. Special attention was paid to determining the level of significance ($P \leq 0.05$ and $P \leq 0.001$), a topographic location and prevalence of cerebral differences. The statistics of changes in the EEG α-power sub-ranges was determined under the averaged data in comparison with the background and other tests by means of student's *t*-test (Microsoft Excel).

3. Results and Discussion

Any aural perception and manual playback of monophonic simple patterns by fingers of the left hand were provided with the reduction of the EEG α-oscillations in the right anterior temporal and central areas of the cerebral cortex as related to the background ($P \leq 0.05$) (Table 1, Fig. 1: 1-2).

Such a localization of changes corresponds to the cortical projections of acoustic and motor reactions provided simple automated sensori-motor activities [2, 12]. A wide capacity of the EEG α-oscillation decrease was occurred in the posterior frontal, temporal, central, parietal and occipital areas of the cortex of both hemispheres against the background ($P \leq 0.05$) (Fig. 1: 1-3) during the performance of the task with the right hand fingers. According to data pointed out in literary sources [1-3, 13] such dynamic shifts became the criterion of the increasingly larger role of non-specific ascending activation processes (bottom-up) related to the processing of the sensory stimuli, sensory-spatial imagination, implementation and programming of the subjectively more complex motor activity with a non-leading (right) hand. However, the significance of detected changes was higher in the right anterior temporal and central and left parietal areas ($P \leq 0.001$). Increased activation processes in the right hemisphere in terms of the activity carried out by both hands may be caused by the dominant role of this hemisphere in the formation of innervation impacts on the peripheral neuro-motor apparatus in left-handers. The performed task laterality changes were followed by the reduced capacity of the EEG α-oscillations in the left temporal and parietal lobe cortex during the activity carried out with the right hand ($P \leq 0.05$), in comparison with left (Fig. 1: 2-3).

During the aural perception and playback of polyphonic rhythmic patterns with fingers of either the left or right hand, a power decrease of the EEG α-oscillations was found in the posterior frontal, temporal and central leads ($P \leq 0.05$) emphasizing in the right anterior temporal and central areas of the cortex ($P \leq 0.001$) (Table 1, Fig. 1: 1-4, 1-5). Appointed

Table 1 Dynamics of the EEG power fluctuations in the α-range (M ± m, μV²) in left-handed men.

Zone \ Test	The functional status of rest	Perception and playback of monophonic rhythmical patterns		Perception and playback of polyphonic rhythmical patterns	
		by left hand	by right hand	by left hand	by right hand
Fz	132.7 ± 7.1	122.8 ± 8.5	109.4 ± 5.9	112.2 ± 6.8	107.7 ± 6
Cz	173.3 ± 9.5	153.5 ± 11.2	138.1 ± 7.6	144.2 ± 9.1	141.5 ± 8.4
Pz	295.2 ± 22.5	307.4 ± 32	243.2 ± 18.7	281.3 ± 26.6	252.3 ± 20.5
Left hemisphere					
Fp1	89.4 ± 4.9	92.4 ± 6.1	83.4 ± 4.3	77.5 ± 4.2	75.8 ± 4.0
F3	126.2 ± 6.7	117.8 ± 8.3	104.5 ± 5.6	105.3 ± 5.9	102.4 ± 5.8
F7	88.1 ± 4.4	91.9 ± 6.4	80.0 ± 4.2	83.1 ± 5.3	74.1 ± 4.1
T3	102.0 ± 5.6	94.3 ± 6.4	80.0 ± 4.2	82.7 ± 4.6	78.4 ± 4.4
C3	165 ± 10.3	135.3 ± 10.5	121.7 ± 7.5	132.8 ± 9.0	126.5 ± 8.3
T5	117.2 ± 7.1	107.2 ± 6.8	90.3 ± 5.2	99.5 ± 6.2	91.0 ± 5.5
P3	233.1 ± 16.1	206.4 ± 18.2	166.1 ± 10.1	184.6 ± 14.4	163.6 ± 10.8
O1	503.1 ± 42.1	508.9 ± 50.1	454.6 ± 37.1	458.9 ± 42.8	420.3 ± 34.2
Right hemisphere					
Fp2	88.7 ± 4.8	92.8 ± 6.4	85.0 ± 4.8	82.2 ± 4.5	72.1 ± 4.2
F4	126.8 ± 6.9	117.2 ± 8.4	103.9 ± 5.6	102.1 ± 5.6	100.8 ± 5.5
F8	86.1 ± 4.3	84.9 ± 5.7	76.7 ± 3.9	77.1 ± 4.3	73.3 ± 3.8
T4	95.5 ± 4.7	74.3 ± 4.9	69.1 ± 3.4	71.4 ± 4.3	74.0 ± 4.0
C4	168.5 ± 9.8	127.0 ± 8.7	117.2 ± 6.3	117.8 ± 6.8	123.6 ± 7.2
T6	138.1 ± 8.9	117.0 ± 9.6	110.9 ± 7.6	105.8 ± 7.1	107.5 ± 8.1
P4	315.5 ± 23.6	273.4 ± 25.5	242.8 ± 18.5	257.2 ± 22.6	241.9 ± 19.3
O2	776.9 ± 61.4	751.8 ± 64.0	739.2 ± 60.4	744.7 ± 64.1	666.6 ± 54.7

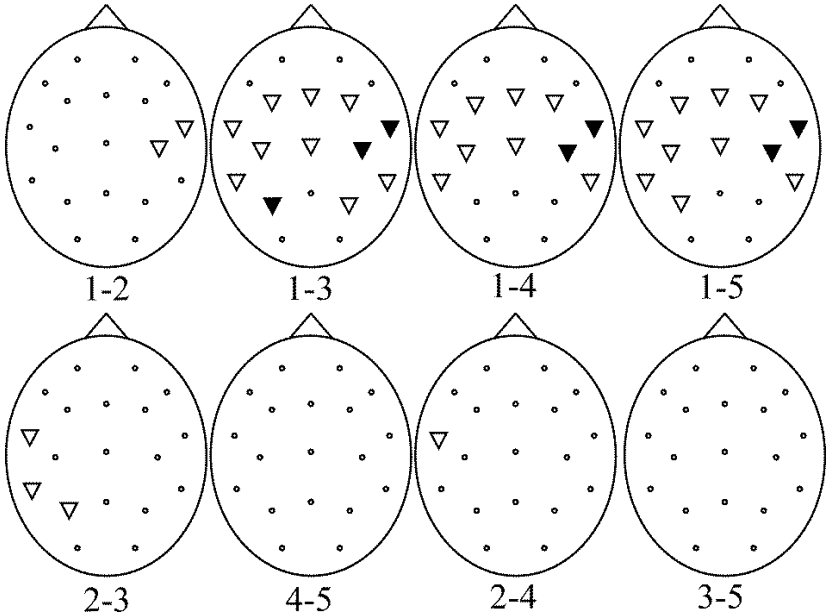

Fig. 1 Dynamics of the EEG power fluctuations in the α-range during the aural perception and playback of mono- and polyphonic patterns by left-handers with their left and right hands.

1: the status of the functional rest; 2 and 3: the aural perception and manual playback of monophonic patterns respectively with left and right hands; 4 and 5: the aural perception and manual reproduction of polyphonic patterns respectively with left and right hands.

△▽the increase (decrease) of parameters in the second test, $0.001 \le P \le 0.05$;

▲▼the increase (decrease) of parameters in the second test, $P \le 0.001$.

patterns indicate the growth of the male attention to activities and increase of the intensity of a nonspecific activation of the cortex [1-3, 13] provided sound and harmonious complications of the pattern structures. The performed task literality changes did not show significant differences (Fig. 1: 4-5).

Strengthening of the generalization changes in the cortex and blocking α-rhythm in the left anterior temporal area ($P \leq 0.05$) as compared to monophonic patterns are a reflection of established activation processes during the aural perception and playback of polyphonic rhythmic patterns with the left hand. Corresponding significant changes were not found in occasion of the right hand activation.

4. Conclusion

The left-handed men's polyphony of the rhythmic pattern soundings is accompanied by processes of the EEG α-oscillation depression against monophonic patterns that are more severe and widespread in the cortex. Indicated patterns point out the greater intensity of the men's use of ascending nonspecific arousal strategies of data processing (bottom-up) provided the sound and harmonious complications of the pattern structure.

The aural perception and playback of rhythmic patterns with both hands were followed by an increased significance of activation processes in the right hemisphere, which may be caused by the dominant role of this hemisphere in left-handers during the formation of the innervation impact on the peripheral neuro-motor apparatus.

More differentiated changes in the cortex during the activation of the left (leading) hand as well as the increasing role of the non-specific activation effects during the task performance with the right (non-leading) hand were detected.

5. Recommendations

In accordance with the obtained results, the actual purpose of the authors' future research is to establish the influence of mono- and polyphony in the sound of rhythmic patterns, and also the lateralization of their manual reproduction on the peculiarities of the electrical activity of the cortex in the EEG α-range of women with the right and left-profiled motor and auditory asymmetry.

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